INSTRUCTION MANUAL

Type 1591-A -AH, -AR, -AHR | VARIAC® AUTOMATIC VOLTAGE REGULATORS

GENERAL RADIO COMPANY
WEST CONCORD, MASSACHUSETTS, USA

A

SPECIFICATIONS

	115-V Models	230-V Models
Output Power	1.0 kVA	0.8 kVA
Output Current	8.7 A	3.4 A
Input-Voltage Range	100 to 130 V	200 to 260 V
Output-Voltage Range (adjustable)	105 to 125 V	210 to 250 V
Max correction	±15 V	±30 V
Frequency	57 to 63 Hz	48 to 63 Hz

Correction Time (cycles): 6 c + 1.5 c/V for 115-V models, 6 c + 0.7 c/V for 230-V models.
Output-Voltage Accuracy: ±0.2% for any combination of line voltage or frequency, load, or power factor.
Temperature Coefficient: Typically 75 ppm/°C.
Power Factor: 0 to 1, leading or lagging.
Response: Rms.
Distortion: None added.
Power Dissipation (approx.): No load, 40 W; full load, 95 W.

ENVIRONMENT

Ambient Temperature (operating): -20 to +52 °C, rack model; -20 to +40 °C, portable model.

Vibration: Rack model, 30 mils pk-pk at 10 to 55 Hz, three planes, 15 min each plane.
Shock (rack model, operating and nonoperating): AF bench-drop test; 30 g for 11 ms.

GENERAL

Accessories Supplied: Spare fuses.
Dimensions (width x height x depth): Portable, 12 3/4 x 9 1/2 x 5 3/8 in. (325 x 245 x 140 mm); rack, 19 x 5 1/4 x 6 3/8 in. (485 x 135 x 165 mm).
Net Weight: Portable, 17 lb (8 kg); rack, 22 lb (10 kg).
Shipping Weight: Portable, 25 lb (11.5 kg); rack, 31 lb (14.5 kg).

Catalog Number	*Description*
	Variac® Automatic Voltage Regulator
1591-9700	1591-A, 115 V, portable
1591-9701	1591-AH, 230 V, portable
1591-9712	1591-AR, 115 V, rack
1591-9713	1591-AHR, 230 V, rack

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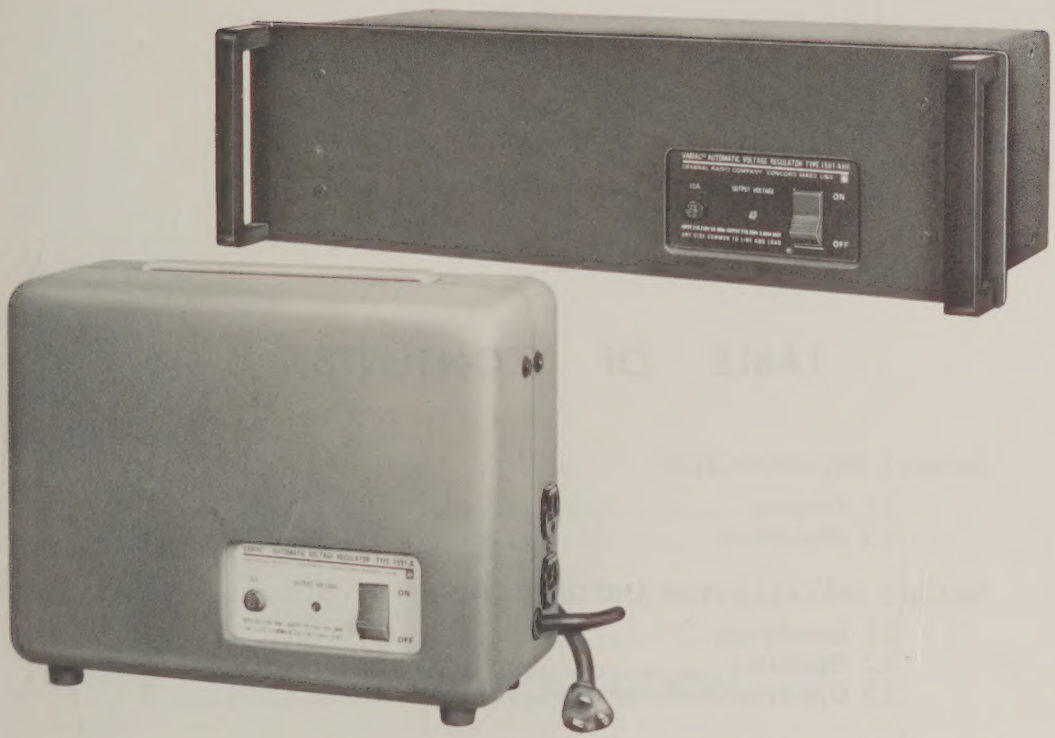

Figure 1-1. Portable and relay-rack Type 1591 Variac® Automatic Voltage Regulator.

CONDENSED OPERATING INSTRUCTIONS

1. Plug the power cord into the unregulated line.
2. Push the ON/OFF switch to ON.
3. Connect the load to be supplied into the output socket(s).

CAUTION

Do not adjust the OUTPUT VOLTAGE control on the front panel fully clockwise without measuring the regulator output voltage. This precaution is necessary to ensure that the output voltage does not exceed the maximum specified level. Refer to paragraph 2.2 for complete details.

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SECTION 1

INTRODUCTION

1.1 PURPOSE.

The Type 1591 VARIAC® Automatic Voltage Regulator is a high-speed electromechanical device used for automatic regulation of line voltage to within 0.2% of a preset voltage level. This regulator is capable of operating on nominal line voltages of 115 V (60 Hz), or 215 V and 230 V (50 to 60 Hz). Large loads can be supplied with an accurately maintained level of voltage, independent of load power factor, and without adding waveform distortion.

The Type 1591 regulator is designed for use in applications that require up to 1 kVA of power. Other General Radio regulators, such as the Type 1581, 1582 series are recommended for higher-powered systems. Two or three units may be connected in a variety of wye or delta configurations for three-phase systems. The Type 1583 is an open-delta, three-phase regulator.

1.2 DESCRIPTION.

1.2.1 GENERAL.

Two basic models are available; portable, and relay rack complete with cabinet (see Figure 1-1). Refer to table 1-1 for a complete listing.

Table 1-1

TYPE 1591 AUTOMATIC VOLTAGE REGULATORS

Type	Model	Input	Output	Catalog Number
1591-A	Portable	100-130 V, 60 Hz	105-125 V, 1 KVA	1591-9700
1591-AH	Portable	200-260 V, 50-60 Hz	210-250 V, 0.8 KVA	1591-9701
1591-AR	Relay Rack	100-130 V, 60 Hz	105-125 V, 1 KVA	1591-9712
1591-AHR	Relay Rack	200-260 V, 50-60 Hz	210-250 V, 0.8 KVA	1591-9713

1.2.2 CIRCUIT.

The basic circuit consists of a special VARIAC autotransformer and a control circuit (see Figure 1-2). The control circuit monitors the line-voltage level and provides a continuous correction signal for adjustment of the output voltage.

The correction signal originates at the bridge circuit which detects changes in the level of the line voltage. Any error voltage is fed through a differential amplifier, an SCR power amplifier, and then to a servomotor which drives the Variac brush. One side of the line input is connected to the autotransformer winding through the brush. As the input level fluctuates, the servomotor changes the brush position and the ratio of input to output across the main winding is changed accordingly. Thus, a constant volts-per-turn is maintained across the autotransformer winding and the output remains at a constant level.

1.2.3 CONTROLS AND CONNECTORS.

Refer to Table 1-2 for a detailed description of the Type 1591 controls and connectors.

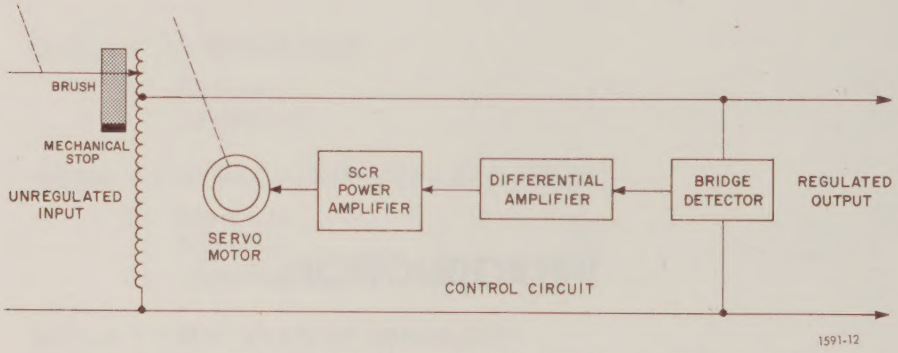

Figure 1-2. Block diagram of the Type 1591 Variac Automatic Voltage Regulator. Brush travel (shaded area) is limited by the upper end of the winding and by a mechanical stop.

Table 1-2

TYPE 1591 CONTROLS AND CONNECTORS

Description	Function	Location
ON/OFF Switch	Connects, or disconnects, unregulated input to the regulator.	Front panel on all models.
OUTPUT VOLTAGE Screwdriver adjustment	Used to adjust R110 in control circuit for desired output-voltage level.	
FUSE	Fuse protection: 10A, Types 1591-A, -AR 4A, Types 1591-AH, -AHR	Rear panel on relay-rack models. Right-hand side on portable models.
Input plug, permanently attached with a 7-foot cable.	Input terminals	
Output sockets, a pair	Two sets of output terminals.	

1.2.4 ACCESSORIES.

A spare fuse is normally furnished with each regulator, see Table 1-3.

Table 1-3
SPARE FUSES

Quantity	Description	Part Number
1	4 A, Buss, Type MDL, for Types 1591-AH, -AHR.	5330-2400
1	10 A., Buss, Type MDL, for Types 1591-A, -AR	5330-2600

SECTION 2

INSTALLATION AND OPERATION

2.1 INSTALLATION.

The Types 1591-A and -AH regulators are used for bench and portable applications. The Types 1591-AR and -AHR are designed for relay-rack use. See Figures 2-1 and 2-2 for dimensions and space requirements.

2.2 OPERATION.

2.2.1 GENERAL.

To operate the regulator, proceed as follows:

a. Plug the power cord in the unregulated line.

b. Push the ON/OFF switch on the front panel to the ON position.

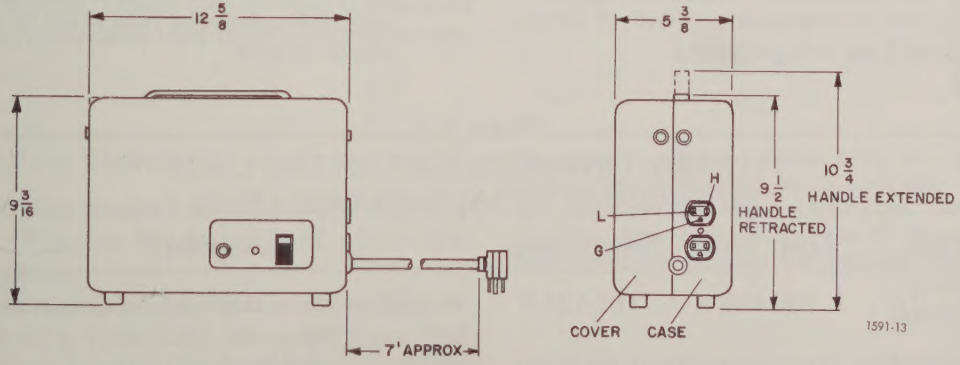

Figure 2-1. Dimensions of portable Type 1591 regulator.

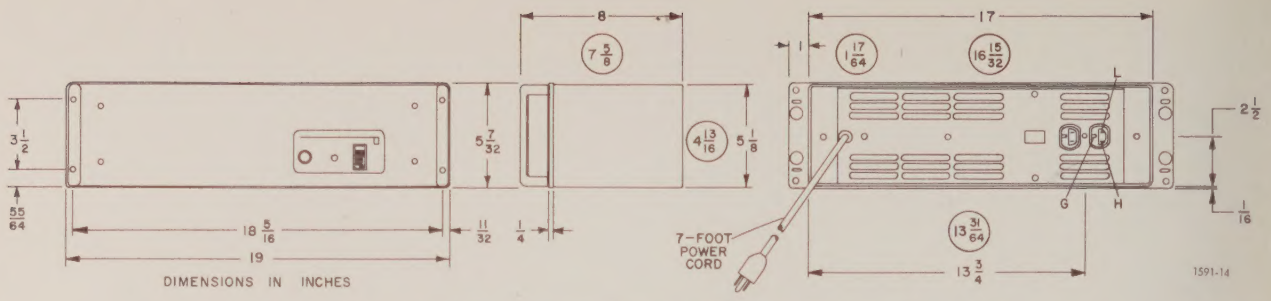

Figure 2-2. Dimensions of relay-rack Type 1591 with and without cabinet. (Circled dimensions apply to the instrument without cabinet.)

NOTE

The output is set to approximately 115 V (1591-A, -AR) or 230 V (1591-AH, -AHR) at the factory. If readjustment is necessary, refer to paragraph 2.2.2.

c. Connect the load to be supplied with regulated voltage into the output socket (s). Two output sockets, connected in parallel, are available for supplying more than one load simultaneously.

The start-up procedure is now completed and the regulator will automatically maintain a constant output as long as input voltage fluctuations do not exceed specifications.

2.2.2 OUTPUT-VOLTAGE ADJUSTMENT.

The regulated output can be set to any level within the limits shown in Table 2-1.

NOTE

If the output voltage is to be adjusted, a warm-up period of about 10 minutes is recommended. Most of the warm-up drift (0.1-to-0.2%) will occur during this time.

To set the output-voltage level, connect an ac (rms) voltmeter across the regulator output. Connection can be made across one set of output socket terminals, or across corresponding points at the input to the external load being supplied. put to the external load being supplied. See Figures 2-1 and 2-2 for the location of the high (H), low (L), and ground (G) terminals at the regulator output socket.

CAUTION

If the voltmeter has one input terminal grounded, make certain that correct polarity is used when the voltmeter is connected to the regulator. A wrong connection will place a short circuit across the regulator and result in a blown fuse.

Adjust the OUTPUT VOLTAGE screwdriver adjustment on the front panel to obtain the desired voltage level reading on the voltmeter. To increase the output voltage, turn the adjustment clockwise; to decrease the voltage, turn the adjustment counter clockwise.

CAUTION

Do not adjust the OUTPUT VOLTAGE control fully clockwise without measuring the regulator output. This precaution is necessary to ensure that the output voltage does not exceed the maximum specified level and result in a blown fuse in the regulator or possible damage to the external equipment connected to the regulator output.

Table 2-1

TYPE 1591, OUTPUT-VOLTAGE SETTING LIMITS WITH RESPECT TO INPUT-VOLTAGE LEVEL

Type	Input Range	Output Range	Limitation
1591-A 1591-AR	100-130 V	105-125 V	Input must be within 15 V of output setting
1591-AH 1591-AHR	200-260 V	210-250 V	Input must be within 30 V of output setting

2.3 OPERATING CHARACTERISTICS.

2.3.1 GENERAL.

The following paragraphs describe the more important operating characteristics of voltage regulators. Test results illustrate typical Type 1591 performance.

2.3.2 ACCURACY.

This characteristic indicates the ability of the regulator to re-establish the output voltage to a specified nominal level. The accuracy of the Type 1591 is specified as ±0.2% for any combination of line voltage or frequency, load, or power factor.

Figure 2-3 shows recordings of the output voltage of two Type 1591 regulators under various combinations of input voltage and load. The upper recording shows the output of a new regulator; the lower recording was obtained from a Type 1591 that had seen a full year of service.

2.3.3 DISTORTION.

The regulator must detect and regulate a specific characteristic of the ac line input. Three choices are available: rms, average, or peak. The rms characteristic is usually chosen as the best compromise. That value, however, may not correspond to the needs of all devices operated from the regulator; many respond to peak or average voltage, rather than the rms value. Therefore, the less distortion introduced by the regulator, the better the regulator's ability to track all three characteristics of the voltage while actually regulating only one.

The plot shown in Figure 2-4a shows the average, peak, and rms components of the output of a Type 1591 which detects and regulates the rms value. The corresponding output waveshape (with no distortion) is also shown. Figure 2-4b shows a similar plot of the performance (with distortion) of another type of regulator.

2.3.4 SPEED OF RESPONSE.

This is the time required for a regulator to restore the output voltage to the desired level, after a line or load disturbance.

Figure 2-5a shows an oscilloscope recording of the response of a Type 1591 when the input level was changed by 2 volts. (The recording shows the positive peaks of the output voltage; rms readings, at these correction speeds, are virtually impossible to obtain.)

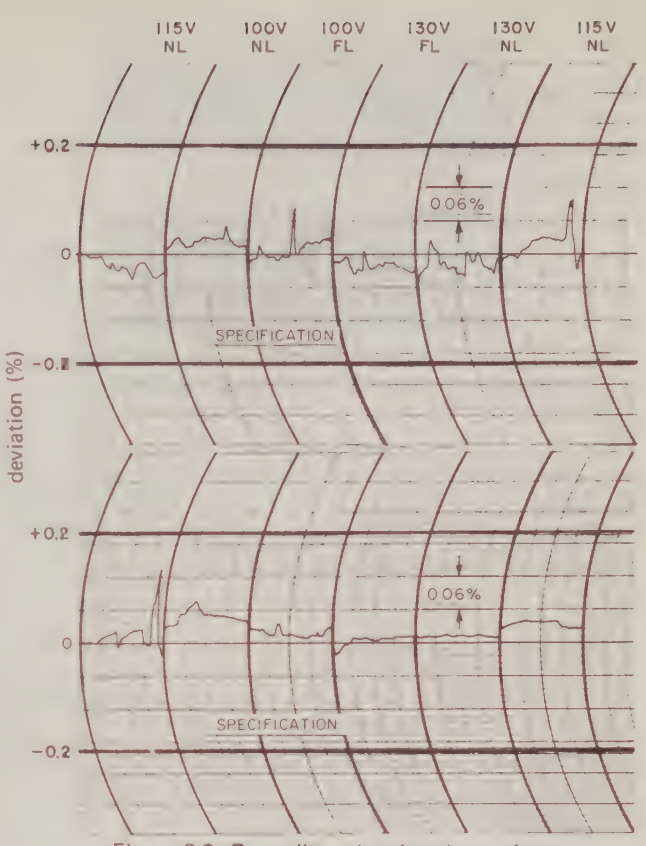

Figure 2-3. Recordings showing the performance of two Type 1591 regulators under changing line and load conditions.
NL = No load FL = Full load

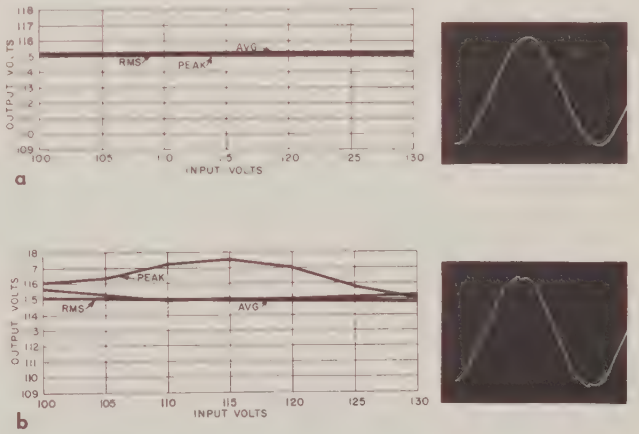

Figure 2-4. Curves showing the ability of a Type 1591 (a) and another type of regulator (b) to track peak and average voltages, while detecting and regulating rms. Any distortion introduced by these regulators is shown in the adjacent waveforms. Load conditions were identical for both instruments.

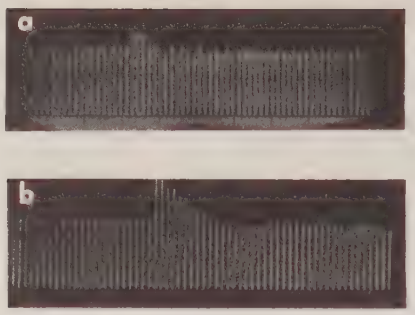

Figure 2-5. Oscilloscope recordings showing typical response of a Type 1591 regulator to a 2-volt (a) and a 10-volt (b) transient.

The response, with a 10-volt change in the input, is shown in Figure 2-5b. In this test, it took about ten cycles for the voltage to reach nominal, followed by a small amount of overcorrection.

2.3.5 LOAD EFFECTS.

Load changes have little effect on the performance of the electromechanical regulator. This stability is due to the low output impedance and close coupling between the input and output of the autotransformer.

Figure 2-6 shows the output voltages of a Type 1591 (electromechanical) and another type of regulator when both were subjected to identical load variations. The input line voltage was held constant during these tests.

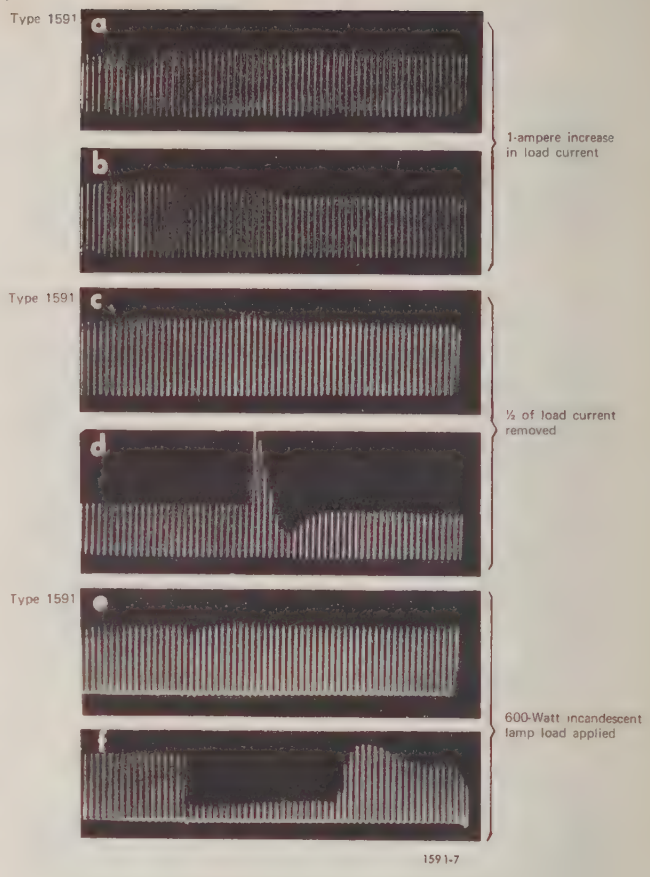

Figure 2-6. Oscilloscope recordings showing typical output voltage of a Type 1591 (a, c, e) and another type of regulator (b, d, f) under varying load conditions.

SECTION 3

PRINCIPLES OF OPERATION

3.1 GENERAL.

The basic function of the Type 1591 Variac Automatic Voltage Regulator is to convert an unregulated line voltage to a regulated output that can be set at a predetermined level.

To accomplish this, the high side of the input line is connected to the brush in the autotransformer, see Figure 3-1. When the input voltage level changes, the brush is moved to a new position on the autotransformer winding. By precise control of the brush position, the volts-per-turn in the winding, and consequently the output voltage, is held constant.

Control of the brush position originates at the detector circuit. This is a bridge circuit connected across the output. When a change in the output voltage is detected, an error signal is fed through a differential amplifier and an SCR power amplifier. and then to a servomotor. The servomotor, in turn, drives the brush in the autotransformer.

3.2 BRUSH CONTROL.

The brush is mechanically limited to about ±15 percent of total travel, see Figure 3-1. This correction range is adequate for most practical regulation applications. The midpoint of this range occurs at a point opposite the output tap.

When the input voltage is equal to the desired output-voltage level, the servomotor positions the brush opposite the output tap.

When the input voltage is greater than the preset output, an error signal is fed to the servomotor and the brush is moved closer to the top of the winding (as shown in Figure 3-1). Thus, the higher input voltage is connected across just enough extra turns in the winding to maintain the same volts-per-turn as when the brush was at the midpoint position.

A voltage drop below the desired output level will result in an error signal and a corresponding change in brush position to a point below the output tap. As in the previous examples, the brush is positioned

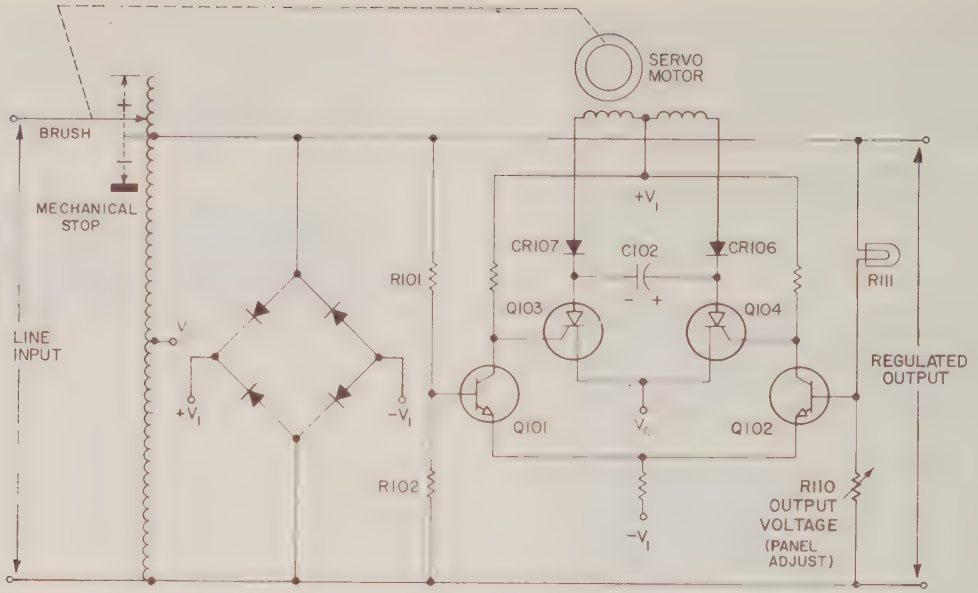

Figure 3-1. Elementary schematic diagram of the Type 1591 regulator. 1591 15

across the proper number of turns to maintain a constant volts-per-turn in the winding.

In this regulator, the Variac brush is driven by a servo motor through a 90:1 gear train. To stabilize the servo system, some damping must be introduced. This function is served in the Type 1591 by an eddy-current brake.

The eddy-current brake, (see Figure 4-4) consists of a high-conductance aluminum disk and two magnets. The disk is attached to the motor rotor and revolves between the two magnets. At slow motor speeds (minor voltage corrections), no significant hold-back torque is generated by the brake, and full torque is available for brush positioning. When larger corrections (faster motor speed) are required, the brake generates considerable hold-back torque. This torque, which is proportional to velocity, provides the damping necessary to stabilize the system.

3.3 CIRCUIT DESCRIPTION

3.3.1 GENERAL.

The servo motor is driven by a control circuit consisting of a bridge detector (R101, R102, R110, R111, Figure 3-1), a differential amplifier (Q101, Q102), and an SCR output stage (Q103, Q104); a total of two transistors and two SCR's form the total active-component complement of this instrument. In spite of the simplicity of this circuit, there is no detectable change in the performance of the 1591 even with a 5-to-1 change in transistor β and a simultaneous 500-to-1 change in sensitivity of the SCR's. In fact, the circuit will tolerate component variations considerably in excess of their specifications for all components but the bridge resistors and lamp.

The relative immunity of regulator performance to component characteristics derives from the unique characteristics of the output signal from a lamp bridge. Lamp bridges have, of course, been used in regulator control circuits before; here, however, use is made of two additional zero crossings resulting from the various frequency components generated in a lamp circuit. These components – the 60-Hz bridge voltage, a 90° out-of-phase component, and a third-harmonic component of the line frequency—combine to produce a waveform similar to that shown in Figure 3-2c. This signal, after amplification, appears as Figure 3-2d. Note that the positions of the zero crossings are independent of amplifier gain. The amplified signal triggers the two SCR's, whose-output waveform is shown in Figure 3-2e. Note that, while the power applied to the motor remains constant, the direction of rotation and torque are functions only of the phase of the control voltage. The phase is in turn a function of the positions of the zero crossings. At unbalance, the 60-Hz correction signal from the bridge serves to move the zero crossings over a range of about 180° for a 1% change in applied bridge voltage. The result is proportional control of torque, independent of amplifier gain and of characteristics of all components except the lamp and the bridge resistors.

The following paragraphs describe the function of the more important components in the regulator control circuit and the functional relationship of the detector, differential amplifier, and the SCR power amplifier as shown in the block diagram of Figure

1-2. Reference is made to the schematic diagrams, Figures 3-1 and 4-8, and the waveforms shown in Figure 3-2.

3.3.2 DETECTOR.

The bridge detector continuously monitors the output-voltage level. When the voltage deviates from the preset level, an error signal is fed to the differential amplifier.

The bridge detector (see Figures 3-1 and 4-8) is made up of resistors R101 and R102 (matched pair). OUTPUT VOLTAGE resistor R110, a special lamp R111, plus additional resistors R108, R109, and R112. Resistor R110 is adjusted to balance the bridge at the desired output-voltage level. The lamp is a GR proprietary design, emphasizing stable short- and long-term operation. Being a thermal device, the lamp responds to the rms value of the applied voltage. The lamp acts as a variable resistor that is controlled by the applied voltage and the bridge will remain in balance until the lamp detects a voltage change in the regulator output.

3.3.3 DIFFERENTIAL AMPLIFIER.

The output of the detector is applied to the bases of transistors Q101 and Q102 in the differential amplifier. The output of the amplifier, at the collectors of Q101 and Q102, is applied to the gate of Q103 and Q104 in the SCR power-amplifier circuit. The SCR's turn on during the positive portion of the applied signal (see Figure 3-2).

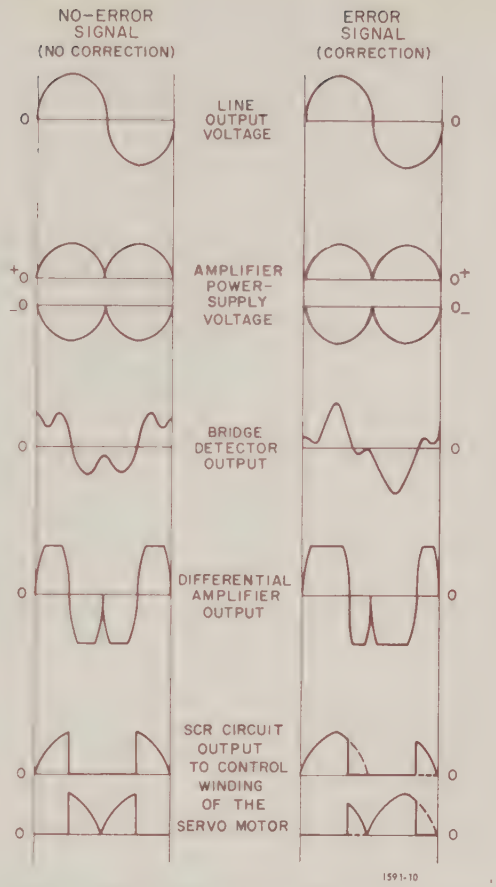

Figure 3-2. Idealized waveforms of the control signal in a Type 1591 Variac Automatic Voltage Regulator.

3.3.4 SCR POWER AMPLIFIER.

This circuit accepts the signal from the differential amplifier and supplies a control signal, in correct phase, to the control winding of the servo motor.

When one of the SCRs is turned on, it cannot be turned off by simply applying a negative gate signal; the anode current must also be reversed. To accomplish this in the Type 1591, commutating capacitor C102 is connected between the anodes of Q103 and Q104. Assume, for example, that Q103 is turned on by a positive-going gate signal. At this time, the anode of Q103 is at ground potential, the anode of Q104 is at B+, and commutating capacitor C102 is charging with a polarity as shown in Figure 3-1. When Q104 is turned on by a positive-going signal, its anode is brought to ground potential, C102 discharges, and a reverse potential is applied to Q103. With its anode current reversed, Q103 is turned off and it will not turn on again until a positive signal is applied to its gate.

SECTION 4

SERVICE AND MAINTENANCE

4.1 WARRANTY.

We warrant that each new instrument manufactured and sold by us is free from defect in material and workmanship, and that, properly used, it will perform in full accordance with applicable specifications for a period of two years after original shipment. Any instrument or component that is found within the two-year period not to meet these standards after examination by our factory, District Office, or authorized repair agency personnel will be repaired or, at our option, replaced without charge, except for tubes or batteries that have given normal service.

4.2 SERVICE.

The two-year warranty stated above attests the quality of materials and workmanship in our products. When difficulties do occur, our service engineers will assist in any way possible. If the difficulty cannot be eliminated by use of the following service instructions, please write or phone our Service Department (see rear cover), giving full information of the trouble and of steps taken to remedy it. Be sure to mention the type and serial numbers of the instrument.

Before returning an instrument to General Radio for service, please write to our Service Department

or nearest District Office, requesting a Returned Material Tag. Use of this tag will ensure proper handling and identification. For instruments not covered by the warranty, a purchase order should be forwarded to avoid unnecessary delay.

4.3 MINIMUM PERFORMANCE STANDARDS.

The following procedure for checking performance specifications is recommended for incoming inspection or periodic operational testing.

4.3.1 TEST EQUIPMENT.

Table 4-1 lists the equipment recommended for performing the test procedures described in paragraph 4.3.2.

4.3.2 TEST PROCEDURE.

Types 1591-A, -AR. First, observe regulator performance under no-load conditions. Set up the circuit shown in Figure 4-1 except for the ac voltmeter and the load. Make the following preliminary settings:

1. Differential voltmeter: 115 V, 10% range.
2. Recorder: 0.3% range, 3 in/min chart speed.
3. Type 1591 OUTPUT VOLTAGE: zero deflection on the recorder.

To check regulation, slowly vary the autotransformer output over the regulator input range (100-130 V for Types 1591-A and -AR, refer to Table 2-1). Observe the reading on the differential voltmeter; the reading should not exceed ±0.2%. The recorder trace should remain within ±0.2% of the zero line.

NOTE

Disregard temporary transients caused by large input surges or time-constant problems associated with the ac voltmeter and recorder.

To observe regulation under load conditions, connect the ac voltmeter between the autotransformer and the Type 1591 (see Figure 4-1). Set the autotransformer for nominal output (refer to Table 2-1) as observed on the ac voltmeter, and proceed as follows:

a. Record the differential voltmeter reading.
b. Connect the 1-kW load to the regulator.
c. Again record the differential voltmeter reading.

The two readings should be within ±0.2%, as stated in the specifications.

Types 1591-AH, -AHR. To observe regulation accuracy of the Types 1591-AH and -AHR, follow the same test procedure used for the 115-V regulators. Refer to Table 2-1 for input/output voltage limits to be used.

4.4 ACCESS TO COMPONENTS.

The following procedure is recommended for gaining access to internal components.

NOTE

Disconnect the regulator from all sources of power before disassembly.

4.4.1 PORTABLE MODELS.

•Cover Removal.

a. Place the regulator on a flat surface with the front panel facing upward.

b. Remove four No. 1/4-28 screws and lockwashers from the cover. (One screw is threaded into each side of the cover and the other two threaded into the bottom).

Table 4-1

TYPE 1591 TEST EQUIPMENT

Type	Requirements	Model Recommended
Adjustable autotransformer	Source of ac power, variable from: 100 to 130 V, 10 A (for Types 1591-A, -AR), 200 to 260 V, 5 A (for Types 1591-AH, -AHR).	 GR W10MT3 GR W20HMT3
AC Voltmeter	Range: 0 to 300 V Accuracy: ±2%	GR Electronic Voltmeter, Type 1806
AC Differential rms voltmeter	Range: 0 to 300 V Accuracy: ±0.05% Recorder output: 1 Vdc, 1 k output impedance, chart speed ≅ 3 in/min.	Fluke#931-A
Strip-chart recorder	Center zero, 0.5 - 0 - 0.5 mA.	Esterline-Angus Model AW, Type 424-A.

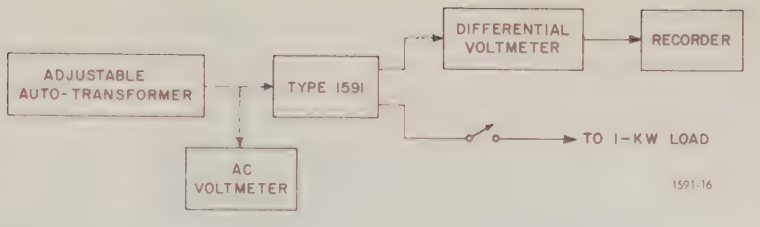

Figure 4-1. Recommended circuit for testing Type 1591 performance specifications.

c. Remove the remaining cover screw (No. 10-32) and lockwasher at the left side of the cover.

d. Remove the cover by sliding it straight up.

NOTE

If the regulator is to be worked on or moved about with the cover removed, remove the handle and spring from the case, as shown in Figure 4-2.

- Cover Installation.

a. Place the regulator on a flat surface with the front panel facing upward.

b. If the handle and flat spring have been previously removed, place them in the slots provided in the case.

c. Install the four No. 1/4-28 and one No. 10-32 screws, with their respective lockwashers, that were removed in steps b and c (Cover Removal).

- Case Removal.

a. Remove the cover and stand the regulator on its remaining two feet (see Figure 4-2).

b. Remove the two No. 10-32 screws and lockwashers (A, Figure 4-2) threaded through the left side of the case and into the end of the autotransformer.

c. Stand the regulator on end, with the etched board facing upward (see Figure 4-3).

d. Remove the four No. 10-32 screws, (B, Figure 4-2) and lockwashers from the back of the case.

e. Swing the internal assembly out of the case as shown in Figure 4-3. The etched board and autotransformer assembly are now accessible.

NOTE

If it is necessary to remove the internal assembly completely from the case, remove a single screw (C, Figure 4-3) located between the two output sockets. The sockets can then be removed from the case along with the internal assembly.

- Case Installation.

a. Place the case on a flat surface, vented side down.

b. Position the end of the autotransformer (left side, facing the front panel) to align the two holes in the end of the autotransformer with corresponding holes in the case. Install the two No. 10-32 screws (A, Figure 4-2) and lockwashers previously removed. (Do not fully tighten screws at this time.)

c. Hold the internal assembly in place and stand the instrument on its two feet as shown in Figure 4-2.

d. Install the four No. 10-32 screws (B, Figure 4-2) and lockwashers previously removed.

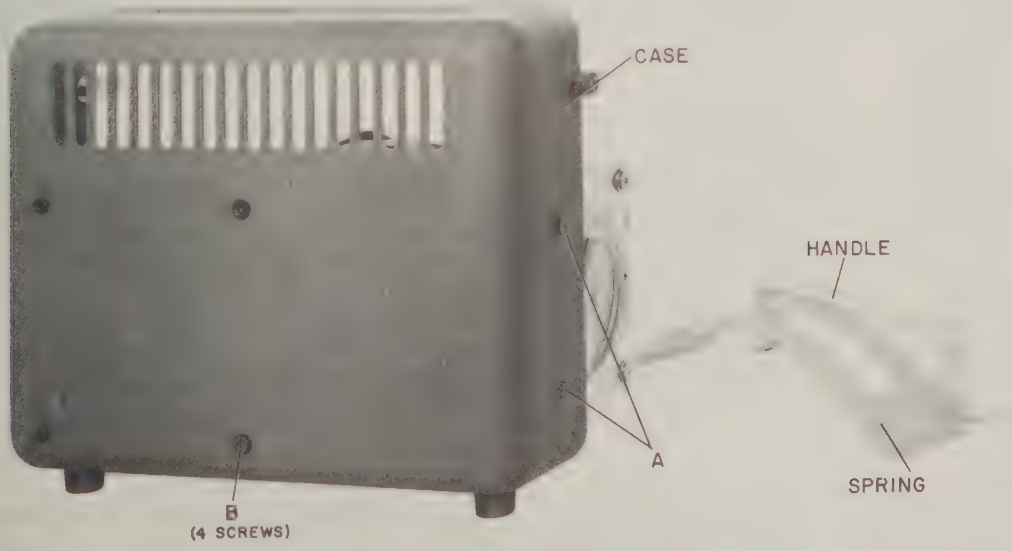

Figure 4-2. Portable Type 1591 with cover removed.

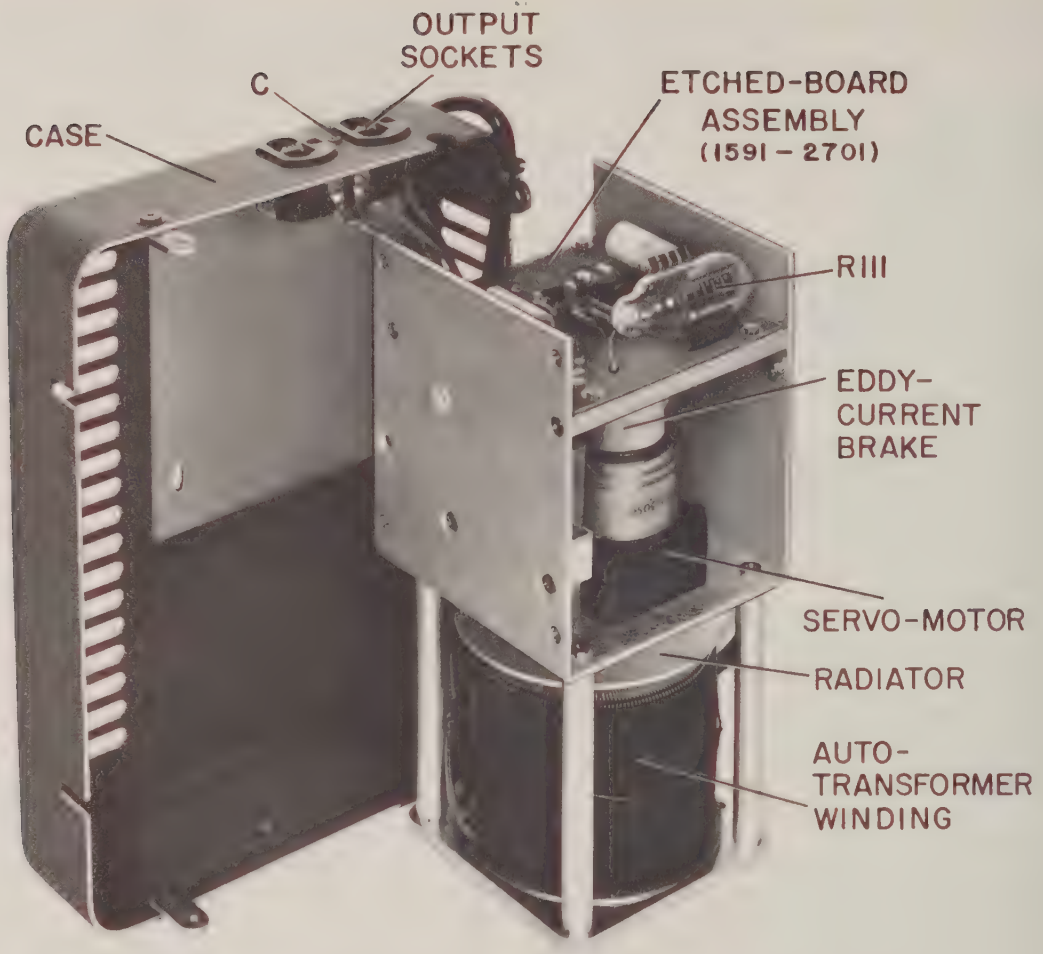

Figure 4-3. Portable Type 1591-A with internal assembly removed from the case.

NOTE

Reinstall the output sockets if they have been previously removed (see Figure 4-3).

e. Tighten all screws.

4.4.2 RELAY-RACK MODELS.

•Cabinet Removal.

a. Remove the two No. 10-32 screws and lockwashers from the two narrow panels at the back of the cabinet.

b. Slide the cabinet straight back to remove it from the regulator.

•Cabinet Installation.

a. To install the cabinet, reverse the procedure described in steps a and b above (Cabinet Removal).

4.5 FUSES.

Fuses for the Type 1591 regulators are accessible for replacement on the front panel. Refer to Table 1-3 for correct fuse ratings.

4.6 CONVERSION TO 215-V LINE OPERATION.

The Type 1591-AH and -AHR regulators normally operate at a 230-V (nominal) line voltage. They can be modified to operate on 215-V (nominal); see Figure 4-8 for conversion instructions.

4.7 EDDY-CURRENT BRAKE.

The eddy-current brake is mounted on the end of the autotransformer motor shaft. The brake assembly is composed of an aluminum disc, two magnets, and a magnet spacer. See Figure 4-4. In operation, the disc rotates (with the motor shaft) in the magnetic field between the two magnets. The spacer maintains the correct gap between the magnets to allow the disc to rotate.

If the eddy-current brake becomes noisy, or fails to operate properly, observe the disc in operation and realign it if necessary:

a. Disconnect the regulator from the line

b. Grasp the magnet spacer and pull the spacer and the outer magnet directly away from the end of

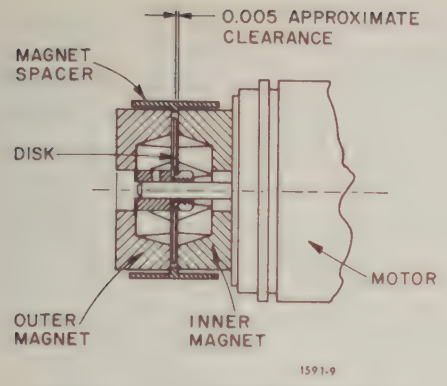

Figure 4-4. Cross-section view of the eddy-current brake mounted on the servomotor shaft of a Type 1591 regulator.

the motor shaft (rotate spacer slightly for easier removal).

c. Manually rotate the radiator (see Figure 4-5) while observing the movement of the disc in the eddy current brake. The disc should rotate with the shaft and it should not contact the face of the inner magnet. If necessary, bend the disc so that it rotates freely. The disc can be easily bent with finger pressure; the use of metal tools is not recommended.

d. To reassemble, slide the spacer and outer magnet on to the end of the motor shaft.

4.8 AUTOTRANSFORMER MAINTENANCE.

The following paragraphs describe recommended procedure for maintaining the autotransformer.

4.8.1 CLEANING.

If the regulator is stored unused in a dirty or dust atmosphere for a long period of time, the brush track should be inspected and cleaned. (A small amount of dirt or dust on the track will be wiped clean by brush action, and no cleaning is required.) When cleaning the brush track, use a soft cloth and a safe solvent such as alcohol or "white" (nonleaded) gasoline.

CAUTION

Do not use abrasives on the contact surface of the autotransformer winding.

4.8.2 LUBRICANTS.

All bearings and gears are factory (permanently) lubricated with MIL-approved oils and greases. No further lubrication should be necessary during the life of the regulator.

4.8.3 BRUSH REPLACEMENT.

Inspect the brush assembly periodically. Note any uneveness of wear or evidence of arcing or pitting of the brush-track surface. Excessive load current accelerates brush deterioration and can damage the autotransformer winding. Rapid brush failure is a sign of overload. Time between inspections should be determined by the user, who should consider variable operating conditions such as amount of use, load characteristics, and operating environment.

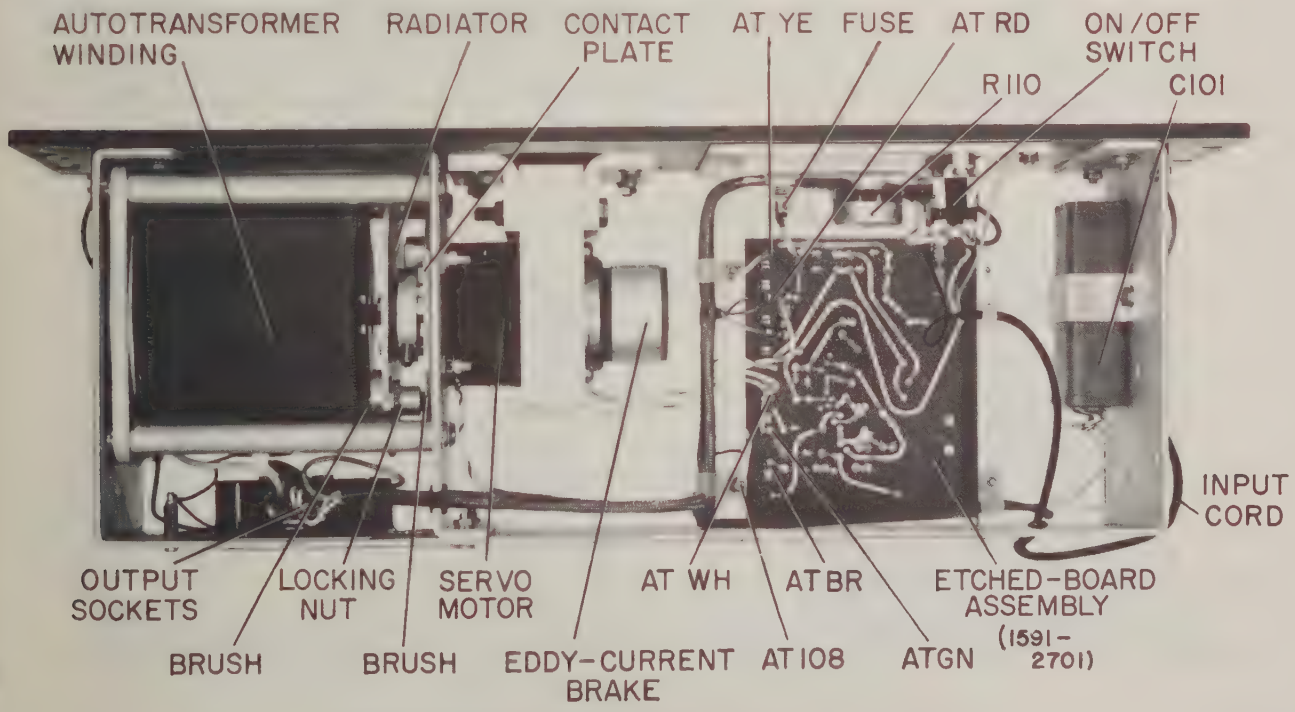

Figure 4-5. Bottom interior view of a relay-rack Type 1591-AR.

Two brushes are used; one brush on the brush tracks of the autotransformer winding and the other on the contact plate. Measure the length of the brush used on the autotransformer winding to determine if a replacement brush should be installed. When new, the brush length is approximately 1/8 inch. When the brush is worn to about 1/16-inch in length, replacement is recommended. Beyond this point, the brush will still operate satisfactory for a period of time, but a built-in stop will eventually cause the brush to lose contact and considerable damage (from arcing) to the winding may result.

Replacement brush assemblies (includes both brushes) are listed in Table 4-2.

Table 4-2

TYPE 1591 REPLACEMENT BRUSH ASSEMBLIES

Regulator	Regulator Output	Brush Assembly
Type	Voltage	Catalog Number
1591-A, -AR	105-125 V	1591-2020
1591-AH, -AHR	210-250 V	1591-2021

To replace the brush assembly:

a. Loosen (do not remove) the brush-holder locking nut (see Figure 4-5) with a 5/8-inch, open-end wrench. The entire brush assembly will now slide easily out of the instrument.

b. Push the brush assembly out of the brush holder.

c. Insert a new brush assembly into the holder. The narrow brush (with a keyed collar) is inserted first; this brush will contact the autotransformer winding when assembly is completed.

d. Slide the entire assembly into place on the radiator and tighten the locking nut.

e. Newly installed, or reinstalled, brushes must be properly seated. With the power off, place a piece of abrasive cloth between the brush and its contact surface, and swing the brush back and forth a few times. Both brushes in the assembly must be seated. Blow out all residue before operating the regulator.

The abrasive side of the cloth must be facing the brush surface. Waterproof, silicon-carbide, 3M "WET-ORDRY" #320 cloth is recommended.

4.9 LAMP REPLACEMENT.

Replacement lamps must be purchased from General Radio. Refer to the parts list for the catalog (ordering) number.

4.10 TEST VOLTAGES.

Test voltages are shown on the complete schematic diagram, Figure 4-8. Test conditions for making these measurements are included.

4.11 TROUBLE ANALYSIS.

If the regulator has no output, make the following preliminary observations:

a. Make certain that line voltage is normal and that it is properly connected to the regulator input.

b. Check for a blown fuse. A blown fuse is probably due to the load connection shorting the regulator output or the OUTPUT VOLTAGE was improperly adjusted. For further discussion of both problems, refer to paragraph 2.2.2.

If the difficulty still exists, measure the output voltage between AT YE and AT BR (see Figure 4-8), and then measure the 51-Vdc supply voltages.

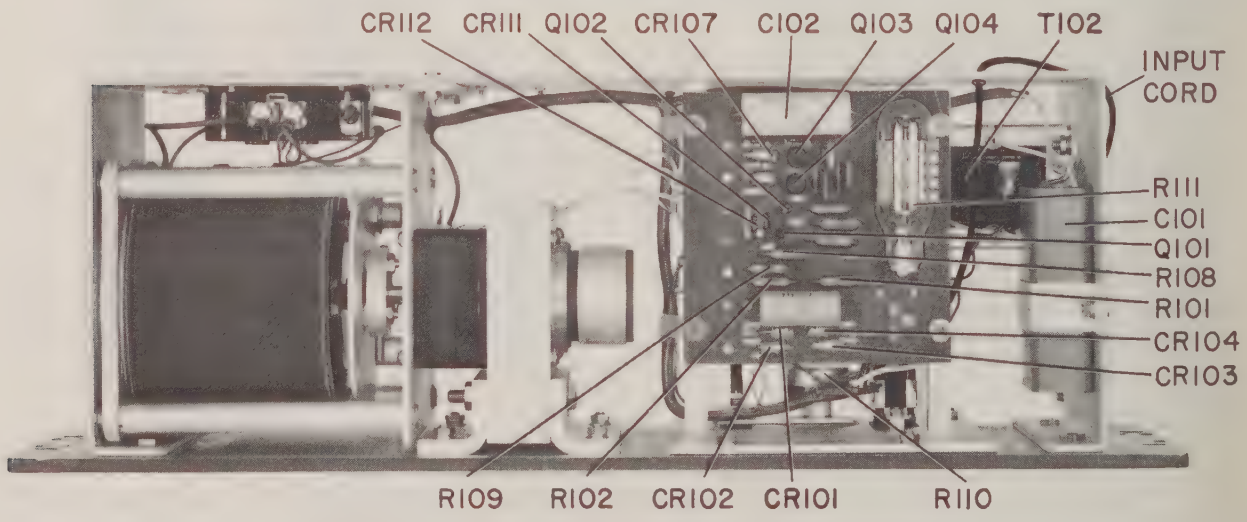

Figure 4-6. Top interior view of a relay-rack Type 1591-AHR.

If the preceeding steps have not isolated the problem area, follow the procedure outlined in Table 4-3 and observe the remaining test voltages in Figure 4-8.

NOTE

As a general rule-of-thumb, the voltages shown on the schematic (Figure 4-8) may vary by as much as 10% and still be considered normal. Remember, however, that these voltages are based on the output, measured between AT YE (High) and AT RD, being set at nominal (see Voltage Measurement Conditions, Figure 4-8). In a defective regulator, all voltages will be directly proportional to the output voltage.

Table 4-3

TYPE 1591 TROUBLE ANALYSIS
(See Figures 4-5 thru 4-8)

Symptom	Probable Cause
Poor Regulation, Unit Noisy and Oscillates.	• Q103 or Q104 shorted. • Eddy-current brake loose or rubbing (refer to paragraph 4.7).
No Regulation, Low Output Voltage.	• Q103, Q104, CR105, or CR107 open. • Q101 or Q102 open or shorted. • CR111 or CR112 shorted. • One motor winding open: check for low voltage at AT GN or AT WH. • R111 open • R102, R108, R109 or R110 open.
Poor Regulation	• DC supply faulty (see Figure 4-8 for correct supply voltages): check • CR101 thru CR104.
No Regulation, No Change in Output	• C102 shorted.
High Regulator Output, Variac Hums.	• R101 open.

FEDERAL MANUFACTURERS CODE

From Federal Supply Code for Manufacturers Cataloging Handbooks H4-1 (Name to Code) and H4-2 (Code to Name) as supplemented through June, 1967.

Code	Manufacturers Name and Address
00192	Jones Mfg. Co., Chicago, Illinois
00194	Walsco Electronics Corp., Los Angeles, Calif.
00656	Aerovox Corp., New Bedford, Mass.
01009	Alden Products Co., Brockton, Mass.
01121	Allen-Bradley, Co., Milwaukee, Wisc.
01295	Texas Instruments, Inc., Dallas, Texas
02114	Ferroxcube Corp. of America, Saugerties, N. Y. 12477
02606	Fenwal Lab. Inc., Morton Grove, Ill.
02660	Amphenol Electronics Corp., Broadview, Ill.
02768	Fastex Division of Ill. Tool Works, Des Plaines, Ill. 60016
03508	G. E. Semiconductor Products Dept., Syracuse, N. Y. 13201
03636	Grayburne, Yonkers, N. Y. 10701
03888	Pyrofilm Resistor Co., Cedar Knolls, N. J.
03911	Clairex Corp., New York, N. Y. 10001
04009	Arrow, Hart and Hegeman Electric Co., Hartford, Conn. 06106
04713	Motorola Semi-Conduct Product, Phoenix, Ariz. 85008
05170	Engineered Electronics Co., Inc., Santa Ana, Calif. 92702
05624	Barber-Colman Co., Rockford, Ill. 61101
05820	Wakefield Eng., Inc., Wakefield, Mass. 01880
07127	Eagle Signal Div. of E. W. Bliss Co., Baraboo, Wisc.
07261	Avnet Corp., Culver City, Calif. 90230
07263	Fairchild Camera and Instrument Corp., Mountain View, Calif.
07387	Birtcher Corp., No. Los Angeles, Calif.
07595	American Semiconductor Corp., Arlington Heights, Ill. 60004
07828	Bodine Corp., Bridgeport, Conn. 06605
07829	Bodine Electric Co., Chicago, Ill. 60618
07910	Continental Device Corp., Hawthorne, Calif.
07983	State Labs Inc., N. Y., N. Y. 10003
07999	Amphenol Corp., Borg Inst. Div., Delavan, Wisc. 53115
08730	Vemaline Prod. Co., Franklin Lakes, N. J.
09213	General Electric Semiconductor, Buffalo, N. Y.
09823	Burgess Battery Co., Freeport, Ill.
09922	Burndy Corp., Norwalk, Conn. 06852
11599	Chandler Evans Corp., W. Hartford, Conn.
12498	Teledyn Inc., Crystalonics Div., Cambridge, Mass. 02140
12672	RCA Commercial Receiving Tube and Semi-conductor Div., Woodridge, N.J.
12697	Clarostat Mfg. Co. Inc., Dover, N. H. 03820
12954	Dickson Electronics Corp., Scottsdale, Ariz.
13327	Solitrone Devices, Tappan, N. Y. 10983
14433	ITT Semiconductors, W. Palm Beach, Florida
14655	Cornell Dubilier Electric Co., Newark N. J.
14674	Corning Glass Works, Corning, N. Y.
14936	General Instrument Corp., Hicksville, N. Y.
15238	ITT, Semiconductor Div. of Int. T. and T, Lawrence, Mass.
15605	Cutler-Hammer Inc., Milwaukee, Wisc. 53233
16037	Spruce Pine Mica Co., Spruce Pine, N. C.
19701	Electra Mfg. Co., Independence, Kansas 67301
21335	Fafnir Bearing Co., New Briton, Conn.
24446	G. E. Schenectady, N. Y. 12305
24454	G. E., Electronic Comp., Syracuse, N. Y.
24455	G. E. (Lamp Div), Nela Park, Cleveland, Ohio
24655	General Radio Co., W. Concord, Mass 01781
26806	American Zettler Inc., Costa Mesa, Calif.
28520	Hayman Mfg. Co., Kenilworth, N. J.
28959	Hoffman Electronics Corp., El Monte, Calif.
30874	International Business Machines, Armonk, N.Y.
32001	Jensen Mfg. Co., Chicago, Ill. 60638
35929	Constanta Co. of Canada Limited, Montreal 19, Quebec
37942	P. R. Mallory and Co. Inc., Indianapolis, Ind.
38443	Marlin-Rockwell Corp., Jamestown, N. Y.
40931	Honeywell Inc., Minneapolis, Minn. 55408
42190	Muter Co., Chicago, Ill. 60638
42498	National Co. Inc., Melrose, Mass. 02176
43991	Norma-Hoffman Bearings Corp., Stanford, Conn. 06904
49671	RCA, New York, N. Y.
49956	Raytheon Mfg. Co., Waltham, Mass. 02154
53021	Sangamo Electric Co., Springfield, Ill. 62705
54294	Shallcross Mfg. Co., Selma, N. C.
54715	Shure Brothers, Inc., Evanston, Ill.
56289	Sprague Electric Co., N. Adams, Mass.
59730	Thomas and Betts Co., Elizabeth, N. J. 07207
59875	TRW Inc. (Accessories Div), Cleveland, Ohio
60399	Torrington Mfg. Co., Torrington, Conn.
61637	Union Carbide Corp., New York, N. Y. 10017
61864	United-Carr Fastener Corp., Boston, Mass.
63060	Victoreen Instrument Co., Inc., Cleveland, Ohio
63743	Ward Leonard Electric Co., Mt. Vernon, N. Y.
65083	Westinghouse (Lamp Div), Bloomfield, N. J.
65092	Weston Instruments, Weston-Newark, Newark, N. J.
70485	Atlantic-India Rubber Works, Inc., Chicago, Ill. 60607
70563	Amperite Co., Union City, N. J. 07087
70903	Belden Mfg. Co., Chicago, Ill. 60644
71126	Bronson, Homer D., Co., Beacon Falls, Conn.
71294	Canfield, H. O. Co., Clifton Forge, Va. 24422
71400	Bussman Mfg. Div. of McGraw Edison Co., St. Louis, Mo.
71590	Centralab, Inc., Milwaukee, Wisc. 53212
71666	Continental Carbon Co., Inc., New York, N. Y.
71707	Coto Coil Co. Inc., Providence, R. I.
71744	Chicago Miniature Lamp Works, Chicago, Ill.
71785	Cinch Mfg. Co. and Howard B. Jones Div., Chicago, Ill. 60624
71823	Darnell Corp., Ltd., Downey, Calif. 90241
72136	Electro Motive Mfg. Co., Willmington, Conn.
72259	Nytronics Inc., Berkeley Heights, N. J. 07922
72619	Dialight Co., Brooklyn, N. Y. 11237
72699	General Instrument Corp., Capacitor Div., Newark, N. J. 07104
72765	Drake Mfg. Co., Chicago, Ill. 60656
72825	Hugh H. Eby, Inc., Philadelphia, Penn. 19144
72962	Elastic Stop Nut Corp., Union, N. J. 07083
72982	Erie Technological Products Inc., Erie, Penn.
73445	Amperex Electronics Co., Hicksville, N. Y.
73559	Carling Electric Co., W. Hartford, Conn.
73690	Elco Resistor Co., New York, N. Y.
73899	J. F. D. Electronics Corp., Brooklyn, N. Y.
74193	Heinemann Electric Co., Trenton, N. J.
74861	Industrial Condenser Corp., Chicago, Ill.
74970	E. F. Johnson Co., Waseca, Minn. 56093
75042	IRC Inc., Philadelphia, Penn. 19108
75382	Kulka Electric Corp., Mt. Vernon, N. Y.
75608	Linden and Co., Providence, R. I.
75915	Littelfuse, Inc., Des Plaines, Ill. 60016
76005	Lord Mfg. Co., Erie, Penn. 16512
76487	James Millen Mfg. Co., Malden, Mass. 02148
76545	Mueller Electric Co., Cleveland, Ohio 44114
76684	National Tube Co., Pittsburg, Penn.
76854	Oak Mfg. Co., Crystal Lake, Ill.
77147	Patton MacGuyer Co., Providence, R. I.
77166	Pass-Seymour, Syracuse, N. Y.
77263	Pierce Roberts Rubber Co., Trenton, N. J.
77339	Positive Lockwasher Co., Newark, N. J.
77542	Ray-O-Vac Co., Madison, Wisc.
77630	TRW, Electronic Component Div., Camden, N. J. 08103
77638	General Instruments Corp., Brooklyn, N. Y.
78189	Shakeproof Div. of Ill. Tool Works, Elgin, Ill. 60120
78277	Sigma Instruments Inc., S. Braintree, Mass.
78488	Stackpole Carbon Co., St. Marys, Penn.
78553	Tinnerman Products, Inc., Cleveland, Ohio
79089	RCA, Commercial Receiving Tube and Semi-conductor Div., Harrison, N. J.
79725	Wiremold Co., Hartford, Conn. 06110
79963	Zierick Mfg. Co., New Rochelle, N. Y.
80030	Prestole Fastener Div. Bishop and Babcock Corp., Toledo, Ohio
80048	Vickers Inc. Electric Prod. Div., St. Louis, Mo.
80131	Electronic Industries Assoc., Washington, D.C.
80211	Motorola Inc., Franklin Park, Ill. 60131
80258	Standard Oil Co., Lafeyette, Ind.
80294	Bourns Inc., Riverside, Calif. 92506
80431	Air Filter Corp., Milwaukee, Wisc. 53218
80583	Hammarlund Co. Inc., New York, N. Y.
80740	Beckman Instruments, Inc., Fullerton, Calif.
81073	Grayhill Inc., LaGrange, Ill. 60525
81143	Isolantite Mfg. Corp., Stirling, N. J. 07980
81349	Military Specifications
81350	Joint Army-Navy Specifications
81751	Columbus Electronics Corp., Yonkers, N. Y.
81831	Filton Co., Flushing, L. I., N. Y
81860	Barry Controls Div. of Barry Wright Corp., Watertown, Mass.
82219	Sylvania Electric Products, Inc., (Electronic Tube Div.), Emporium, Penn.
82273	Indiana Pattern and Model Works, LaPort, Ind.
82389	Switchcraft Inc., Chicago, Ill. 60630
82647	Metals and Controls Inc., Attleboro, Mass.
82807	Milwaukee Resistor Co., Milwaukee, Wisc.
83058	Carr Fastener Co., Cambridge, Mass.
83186	Victory Engineering Corp (IVECO), Springfield, N. J. 07081
83361	Bearing Specialty Co., San Francisco, Calif.
83587	Solar Electric Corp., Warren, Penn.
83740	Union Carbide Corp., New York, N. Y. 10017
84411	TRW Capacitor Div., Ogallala, Nebr.
84835	Lehigh Metal Products Corp., Cambridge, Mass. 02140
84971	TA Mfg. Corp., Los Angeles, Calif.
86577	Precision Metal Products of Malden Inc., Stoneham, Mass. 02180
86684	RCA (Electrical Component and Devices) Harrison, N. J.
88140	Cutler-Hammer Inc., Lincoln, Ill.
88219	Gould Nat. Batteries Inc., Trenton, N. J.
88419	Cornell Dubilier Electric Corp., Fuquay-Varina, N. C.
88627	K and G Mfg. Co., New York, N. Y.
89482	Holtzer Cabot Corp., Boston, Mass.
89665	United Transformer Co., Chicago, Ill.
90201	Mallory Capacitor Co., Indianapolis, Ind.
90750	Westinghouse Electric Corp., Boston, Mass.
90952	Hardware Products Co., Reading, Penn. 19602
91032	Continental Wire Corp., York, Penn. 17405
91146	ITT Cannon Electric Inc., Salem, Mass.
91293	Johanson Mfg. Co., Boonton, N. J. 07005
91598	Chandler Co., Wethersfield, Conn. 06109
91637	Dale Electronics Inc., Columbus, Nebr.
91662	Elco Corp., Willow Grove, Penn.
91719	General Instruments, Inc., Dallas, Texas
91929	Honeywell Inc., Freeport, Ill.
92519	Electra Insulation Corp., Woodside, Long Island, N. Y.
92678	Edgerton, Germeshausen and Grier, Boston, Mass.
93332	Sylvania Electric Products, Inc., Woburn, Mass.
93916	Cramer Products Co., New York, N. Y. 10013
94144	Raytheon Co. Components Div., Quincy, Mass.
94154	Tung Sol Electric Inc., Newark, N. J.
95076	Garde Mfg. Co., Cumberland, R. I.
95146	Alco Electronics Mfg. Co., Lawrence, Mass.
95238	Continental Connector Corp., Woodside, N. Y.
95275	Vitramon, Inc., Bridgeport, Conn.
95354	Methode Mfg. Co., Chicago, Ill.
95412	General Electric Co., Schenectady, N. Y.
95794	Ansconda American Brass Co., Torrington, Conn.
96095	Hi-Q Div. of Aerovox Corp., Orlean, N. Y.
96214	Texas Instruments Inc., Dallas, Texas 75209
96256	Thordarson-Meissner Div. of McGuire, Mt. Carmel, Ill.
96341	Microwave Associates Inc., Burlington, Mass.
96906	Military Standards
97966	CBS Electronics Div. of Columbia Broadcasting Systems, Danvers, Mass.
98291	Sealectro Corp., Mamaroneck. N. Y. 10544
98821	North Hills Electronics Inc., Glen Cove, N. Y.
99180	Transitron Electronics Corp., Melrose, Mass.
99378	Atlee Corp., Winchester, Mass. 01890
99800	Delevan Electronics Corp., E. Aurora, N. Y.

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PARTS LIST

Ref. No.	Description	GR Part No.	Fed. Mfg. Code	Mfg. Part No.	Fed. Stock No.
For All Type 1591 Models					
CAPACITORS					
C101	Oil, 3 µF ±10% 600 V	4510-1100	74861	9738SARU	
C102	Plastic, 1.0 µF ±10% 200 V	4860-8275	59875	663 UW, 1.0 µF ±10%	
C103	Ceramic, 0.47 µF ±20% 25 V	4400-2054	80183	5C13, 0.4 µF ±20%	5910-974-5696
C104	Ceramic, 0.47 µF ±20% 25 V	4400-2054	80183	5C13, 0.4 µF ±20%	5910-974-5696
DIODES					
CR101 thru CR104	Type 1N3254	6081-1002	09213	1N3254	5961-082-3988
CR105	Thermistor	6741-1001	24454	6RS20SP4B4	
CR106	Type 1N3254	6081-1002	09213	1N3254	5961-082-3988
CR107	Type 1N3254	6081-1002	09213	1N3254	5961-082-3988
CR108 thru CR112	Type 1N645	6082-1016	24446	1N645	5961-944-8222
RESISTORS					
R101	Film, 5.1 kΩ ±1% 1/2 W	1591-0400	24655	1591-0400	
R102	Film, 5.1 kΩ ±1% 1/2 W	1591-0400	24655	1591-0400	
R103	Film, 16.2 kΩ ±1% 1/2 W	6450-2162	75042	CEC, 16.2 kΩ ±1%	
R104	Film, 16.2 kΩ ±1% 1/2 W	6450-2162	75042	CEC, 16.2 kΩ ±1%	
R105	Composition, 1.8 kΩ ±5% 1/2 W	6100-2185	01121	RC20GF182J	5905-190-8881
R106	Composition, 1.8 kΩ ±5% 1/2 W	6100-2185	01121	RC20GF182J	5905-190-8881
R107	Film, 8.2 kΩ ±1% 1/2 W	6450-1820	75042	CEC, 8.2 kΩ ±1%	5905-794-4209
R108	Film, 887 Ω ±1% 1/2 W	6450-0887	75042	CEC, 887 Ω ±1%	
R109	Film, 887 Ω ±1% 1/2 W	6450-0887	75042	CEC, 887 Ω ±1%	
R110	Potentiometer, 500 Ω ±10%	6050-1100	12697	43WX, 500 Ω ±10%	5905-797-1056
R111	Lamp	5600-1030	71744	CM9-100	
TRANSISTORS					
Q101	Type 2N3415	8210-1103	24454	2N3415	
Q102	Type 2N3415	8210-1103	24454	2N3415	
Q103	Type C6B	8210-1104	24454	C6B	
Q104	Type C6B	8210-1104	24454	C6B	
MISCELLANEOUS					
MO101	MOTOR	1591-2030	24655	1591-2030	
S101	SWITCH, dpst, ON/OFF	7910-0411	39317	#0811	
	Etched-circuit assembly, complete	1591-2701	24655	1591-2701	
	Magnet	5630-0504	82273	#49A122	
	Spacer, magnet	1591-6090	24655	1591-6090	
For Certain Models Only					
F101	Fuse, 4 A (1591-AH, -AHR)	5330-2400	71400	MDL, 4 Amp	
F101	Fuse, 10 A (1591-A, -AR)	5330-2600	71400	MDL, 10 Amp	
PL101	Cable, power (1591-AR)	4200-0900	24655	4200-0900	
	Cable, power (1591-AH, -AHR))	4200-1000	24655	4200-1000	
	Cable, power (1591-A)	4200-2200	24655	4200-2200	
SO101	Socket, output power (1591-A, -AR)	4250-1000	24655	4250-1000	
	Socket, output power (1591-AH, -AHR)	4250-1010	24655	4250-1010	
	Socket, output power (1591-A)	3080-4020	24655	3038-4020	
T101	Transformer, coil and base assembly (1591-AR)	3038-4021	24655	3038-4021	
	Transformer, coil and base assembly (1591-AH)	3038-4030	24655	3038-4030	
	Transformer, coil and base assembly (1591-AHR)	3038-4031	24655	3038-4031	
T102	Transformer Assembly (1591-AH, -AHR)	0345-4150	24655	0345-4150	
	Brush Assembly (1591-A, -AR)	1591-2020	24655	1591-2020	
	Brush Assembly (1591-AH, -AHR)	1591-2021	24655	1591-2021	
	Handles (1591-AR, -AHR)	5360-2012	24655	5360-2012	
	Handle (1591-A, -AH)	1591-8140	24655	1591-8140	
	Spring, handle (1591-A, -AH)	1591-8150	24655	1591-8150	
	Foot (1591-A, -AH)	5260-110	70485	#18, 5/8"	

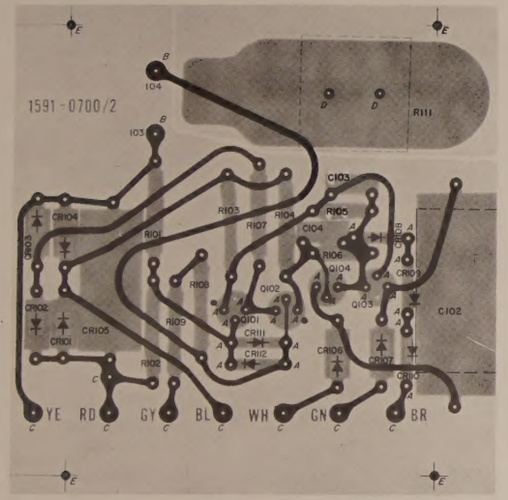
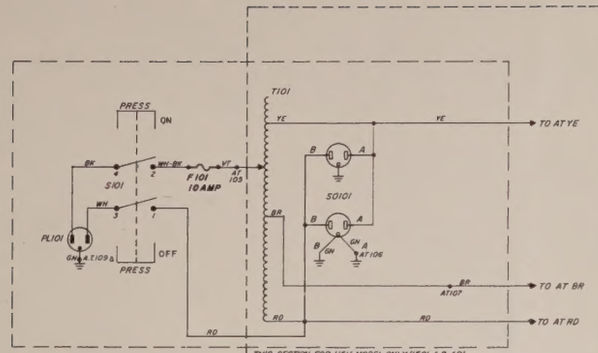
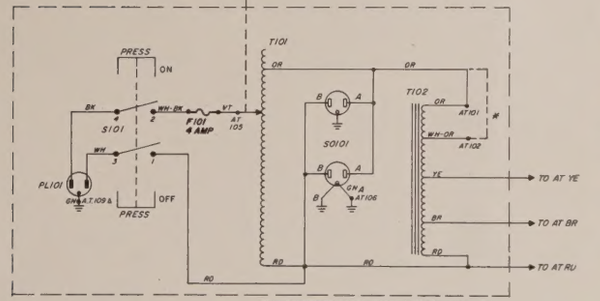


Figure 4-7. Etched-board layout for Type 1591 Variac Automatic Voltage Regulator (P/N 1591-2701).

NOTE: The number appearing on the foil side is not the part number. The dot on the foil at the transistor socket indicates the collector lead.





* NOTE: FOR 215V OPERATION CONNECT ORANGE LEAD FROM S0101 TO AT102 AS INDICATED BY BROKEN LINE
FOR 230V OPERATION MAKE CONNECTION TO AT101 AS INDICATED BY SOLID LINE

Δ FOR 1591-AR & AHR

ANCHOR TERMINALS USED

1591-A (PORTABLE)	AT103, 104, 105 & 106 AT GN, BL, RD, YE, GY, BR, WH
1591-AH (PORTABLE)	AT101, 102, 103, 104, 105 & 106 AT GN, BL, RD, YE, GY, BR, WH
1591-AR (RELAY RACK)	AT103, 104, 105, 106, 107, 108 & 109 AT GN, BL, RD, YE, GY, BR, WH
1591-AHR (RELAY RACK)	AT101, 102, 103, 104, 105, 106, 108 & 109 AT GN, BL, RD, YE, GY, BR, WH

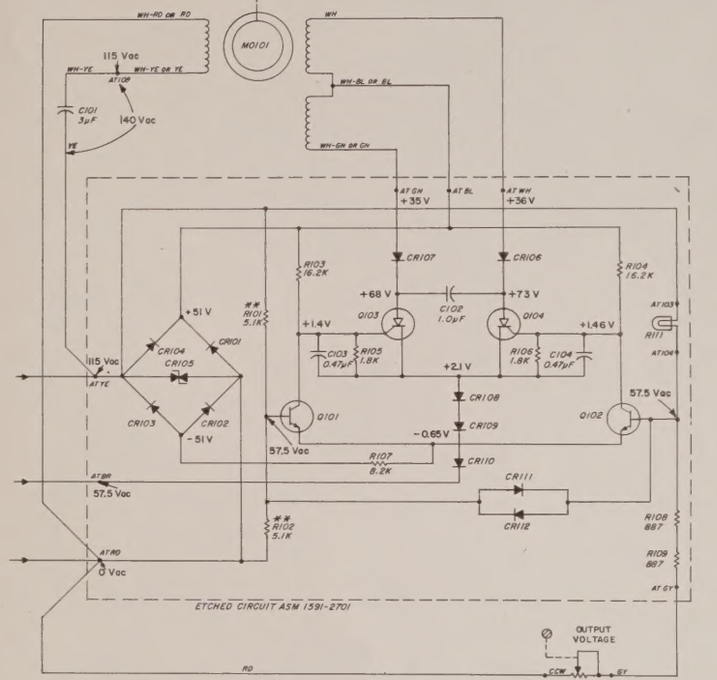
1591-17

NOTE UNLESS SPECIFIED

1. POSITION OF ROTARY SWITCHES SHOWN COUNTERCLOCKWISE.
2. CONTACT NUMBERING OF SWITCHES EXPLAINED ON SEPARATE SHEET SUPPLIED IN INSTRUCTION BOOK.
3. REFER TO SERVICE NOTES IN INSTRUCTION BOOK FOR VOLTAGES APPEARING ON DIAGRAM.
4. RESISTORS 1/2 WATT.
5. RESISTANCE IN OHMS K 1000 OHMS M 1 MEGOHM
6. CAPACITANCE VALUES ONE AND OVER IN MICROFARADS, LESS THAN ONE IN MICROFARADS.
7. ◯ KNOB CONTROL
8. ⊖ SCREWDRIVER CONTROL
9. AT ANCHOR TERMINAL
10. TP TEST POINT

VOLTAGE MEASUREMENT CONDITIONS

OUTPUT set at nominal, 115 V or 230 V.
No load connected to regulator.
All voltages are dc unless otherwise specified.
AT BR is reference for dc measurements (use 20 kΩ/volt meter).
AT RD is reference for all ac measurements except across C101.

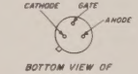


* * RESISTOR PAIR 1591-0400

NOTE

SOME INSTRUMENTS WILL HAVE A RESISTOR (R112) CONNECTED IN PARALLEL WITH R110.
R112 Film, 1.1 kΩ +1% 1/2 W 6450-1110
(Value may be adjusted at the factory)

BOTTOM VIEW OF Q101, Q102



BOTTOM VIEW OF Q103, Q104

Figure 4-8. Schematic diagram for Type 1591 Variac Automatic Voltage Regulator.

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